Report:
U.S. Virgin Islands Summer 1998 Research Trip

Study of the optical properties of Saharan dust over the ocean

Period of Study: <u> 7-15-98 to 8-12-98</u>

NASA Contract: #NA55-31363

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1. Introduction

I conducted a field measurement program from July 15, 1998 to August 12, 1998 at the Virgin Islands Environmental Resource Station (VIERS) at Lameshur, St. John, USVI. The purpose of the program was to study the optical properties of airborne particles in the atmosphere (aerosols). Aerosols directly effect the climate by scattering and absorbing sunlight in the atmosphere and indirectly cause climate effects by serving as cloud condensation nuclei [*Russell et al*., 1997]. Aerosols also interfere with the remote sensing of the earth's surface from satellite sensors because the signals from the surface must pass through the aerosol layers.

I am funded to provide information on the optical properties of aerosols over the ocean in order to correct satellite images of the ocean color. Ocean color measurements are made to determine biologically important ocean parameters, such as the concentration of chlorophyll *a* in a given body of water. The presence of aerosol layers over the water must be accounted for when analyzing the satellite data to insure an accurate analysis is made [*Gordon,* 1997]. In particular, I was measuring two of the key optical properties of aerosols. The first property is referred to as the aerosol optical depth (AOD) and is a measure of the amount of direct sunlight attenuated by the aerosol layers. The spectral dependence of the AOD throughout the visible and near-infared wavelengths also gives information on the size distribution of the aerosols [*Van de Hulst*, 1981]. The second property I was measuring was the vertical profile of the aerosol extinction coefficient (AEC). The AEC is the amount of sunlight scattered and absorbed per unit length by the aerosols. Knowledge of the AEC and also the altitude of the aerosol layers is vital for correct analysis of the ocean color data [*Gordon,* 1997].

The VIERS site was chosen because it is on a small, remote island that is largely free of urban influence and is one of the few easily accessible locations for the study of aerosols over the open ocean. In addition, the primary aerosol species I was interested in studying was Saharan dust. Saharan dust is transported across the Atlantic Ocean during the summer and early fall months [*Prospero*, 1995] and the Virgin Islands are ideally situated to study the dust as it moves across the Atlantic. The influx of Saharan dust perturbs the regional climates of the Caribbean and the Southeastern United States. Also, dust aerosols are difficult to incorporate into satellite correction analysis since there is little historical data on their optical properties. In addition, dust aerosols are often irregular in shape and normal analysis routines that make use of spherical particle assumptions for optical calculations produce inaccurate results [*Mishchenko et al.*, 1997]. *In-situ* data on the real optical properties of dust aerosols over the ocean is needed for the validation and correction analysis of the ocean color measurements.

This report will describe the VIERS site and discuss the instrumentation I deployed during the measurement program. I will also present data that identifies the presence of dust aerosols as well as reasonably clear days and also the altitude of the respective aerosol layers. Finally, I will discuss the measured AOD and AEC profiles of both clear and dusty periods and relate them to data taken during this period using the NASA SeaWiFS ocean color sensor [*Hooker et al*., 1992] currently in orbit.

2. Site and Instrumentation Descriptions

VIERS [*VIERS*, www site, 1998] is located at 18.32^o N latitude and 64.73^o W longitude and includes a marine laboratory located on Great Lameshur Bay and a living area (campground) located a short distance inland from the bay. The elevation of the lab and the campground varies within just a few meters of sea-level, thus for the purposes of this program all data was analyzed assuming an altitude of 0 km. VIERS is bordered to the north (inland) by tall hills of maximum altitude approximately 380 m but has a relatively unobstructed view (within a few meters of sea-level) to the east and southeast (windward). VIERS is located well within the boundaries of the Virgin Islands National Park and its remote location insures that little to no urban aerosols are present.

I deployed three instruments at VIERS during the measurement program. The first two instruments were sunphotometers which are used to measure the AOD and it's spectral dependence. A hand-held sunphotometer was used for the first two weeks, and an automatic sky scanning sunphotometer (Cimel) was used for the remainder of the program. The Cimel [*Holben et al*., 1994] was not functioning during the first two weeks of the program due to problems with it's motor. The Cimel sunphotometer is shown in Figure 1 while operating on the VIERS lab roof.

Figure 1

Figure 1. The Cimel sunphotometer is shown operating on the roof of the VIERS lab. The Cimel is the gray tube pointing skyward from the top of the roof.

The other instrument was a micro-pulse lidar system [*Spinhirne et al.*, 1995] and is shown in Figure 2 while operating at the VIERS campground. The lidar was used to acquire the vertical profiles of the AEC and AOD. The lidar operated throughout the program. However, a problem developed during the first week and resulted in condensation forming on the mirror surfaces of the lidar transmitter-receiver (T-R). Massive condensation on the mirrors prevents successful operation of the lidar, therefore a lidar data was only taken during periods relatively free of visible mirror condensation.

Figure 2

Figure 2. The lidar system is shown operating at the VIERS campground.

3. Cimel and Lidar Data

The data acquired with the Cimel was processed by the AERONET [*NASA-a*, www site, 1998] group at NASA Goddard Space Flight Center and then supplied to me. The Cimel measured the spectral dependence of the AOD from July 29, 1998 to August 8, 1998. This AOD data was used to identify dust dominant periods from clean (normally only sea-salt aerosols) periods using criteria I developed in my Ph.D. dissertation [*Welton*, 1998]. Analysis of the Cimel AOD data as well as a few hand-held sunphotometer AOD measurements has shown that July 27, August 6, and August 8 were clean days free of dust, while July 29, July 31, and August 1 were days with moderate to heavy dust. Consultation of my notes from these days also shows both clean and hazy visual conditions on the appropriate days.

The lidar data acquired on the clean and dusty days mentioned above was analyzed to determine the vertical profile of the AEC at times coincident with the Cimel measurement. The AOD measured with the Cimel was used to calculate the AEC profiles from the lidar data using an algorithm I had developed in my Ph.D. dissertation [*Welton*, 1998]. The best coincident Cimel and lidar data was available on August 1 for the dusty days and August 8 for the clean days. These days were chosen based on overlapping Cimel and lidar measurement times as well as the absence of cirrus clouds (identification of cirrus clouds is possible by inspection of the lidar data) which falsely increase the AOD. The AEC profiles and AOD are shown in Figure 3 for August 1 and August 8.

Figure 3

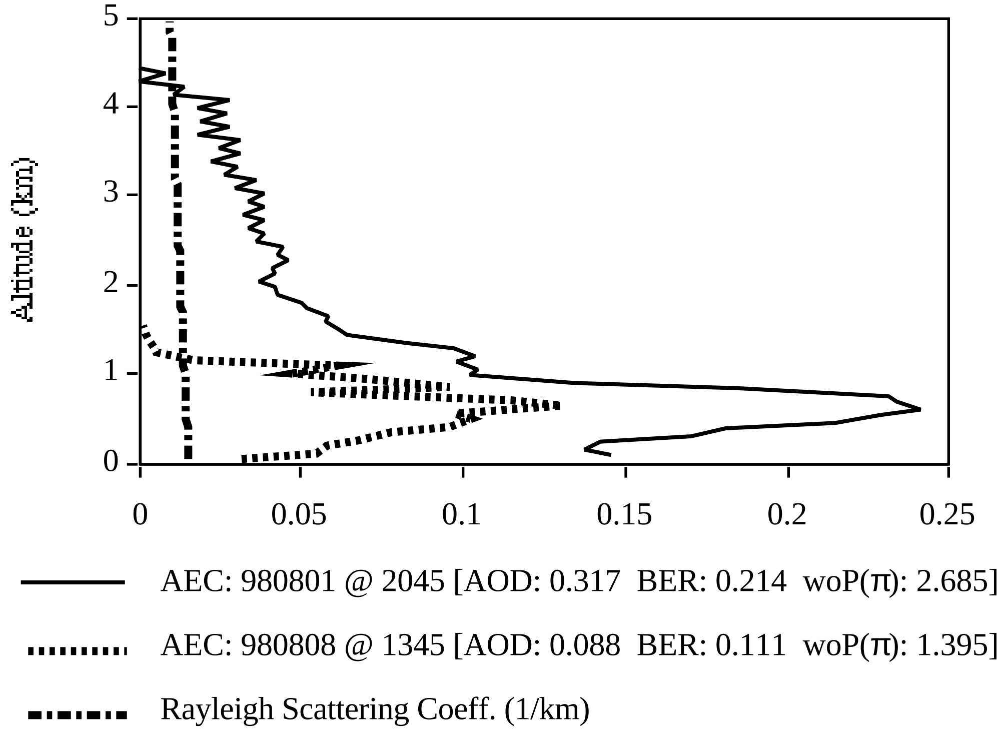

Figure 3. AEC profiles for the August 1 dust period (980801) and the August 8 clean period (980808). The profile due to molecular scattering (Rayleigh) is shown for comparison. The AOD measured on each day is given in the brackets.

The AEC values obtained during the dust period on August 1 are much greater than those measured during clean conditions on August 8. Also, the August 1 AEC values are the same magnitude as dust AEC values I obtained with the lidar during the Aerosol Characterization Experiment 2 (ACE-2) in Tenerife, Canary Islands in 1997. The Figure also shows the clean August 8 aerosols to be confined to a narrow layer extending to only just over 1 km in altitude. However, during the dusty August 1 period the aerosols are seen to extend to 4 km in altitude. Most of the aerosols are located in the boundary layer on this day, but a clear dust layer above the boundary layer is evident.

The AEC values (at each individual altitude) in each profile may not be highly accurate based on the backscatter-extinction ratio (BER) calculated for each profile. The

BER values for both the clean and dusty profiles are quite high and this is usually caused by incorrect AOD values input to the algorithm or a BER values that are not constant with altitude. The Cimel instrument is highly calibrated at the Goddard facility thus the AOD values are most likely correct. The best assumption is that the BER was not constant with altitude during both of these profiles. This was probably less likely with the clean profile as the BER is much closer to values that would be expected for spherical sea-salt particles. Despite possible error in the calculated AEC values, the altitude of the aerosol layers remains unaffected. Thus the altitude range of the clean and dusty periods is accurate and useful information.

4. *In-situ* Results and SeaWiFS Measurements

SeaWiFS data was acquired on August 1 and August 8 for the area surrounding and including the U.S. Virgin Islands. The SeaWiFS data presented here was provided by the NASA Goddard SeaWiFS web site [*NASA-b*, www site, 1998]. Figures 4 and 5 show composite visible wavelength satellite images taken by SeaWiFS over the VIERS site on August 1 and August 8 respectively. Dust is visible in the images as the brown color, clouds appear as white, and clear portions of sky are blue due to the ocean surface. Also, sunglitter from the ocean surface is present in the middle portion of each image and unfortunately encompasses the VIERS site in Figure 4. However, Figure 4 clearly shows the VIERS site to be under a large dust layer on August 1 that extends far south of the island as much of this portion of the image is most likely dust due to its hazy distinctive brown color. Conversely, Figure 5 shows the VIERS site to be under clear sky save for clouds to the northeast and southwest; dust is visible far to the south of the site on this day.

Figure 4

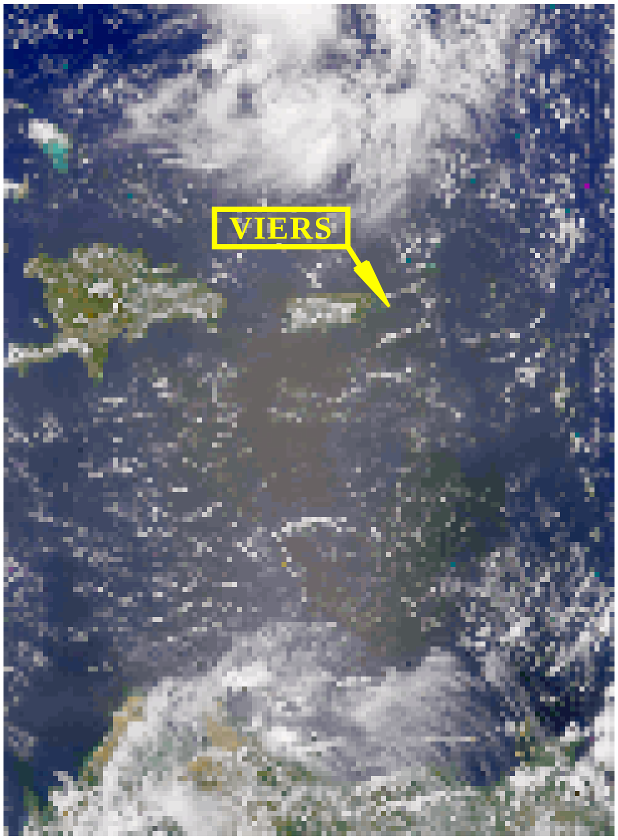

Figure 4. SeaWiFS visible image showing the VIERS site under a large dust layer. Dust appears brown, clouds white, and clear sky portions are blue due to the ocean surface. Sunglitter, present in the middle portion of the image, appears as a gray-like color.

Figure 5

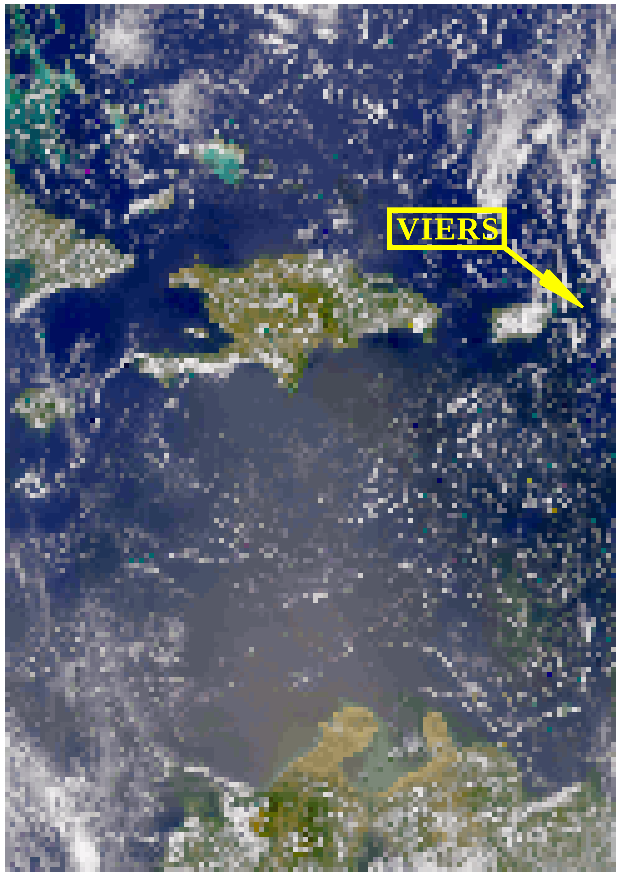

Figure 5. SeaWiFS visible image on August 8 showing the VIERS site under clear sky although surrounded by clouds to the northeast and southwest. Dust appears brown, clouds white, and clear sky portions are blue due to the ocean surface. Sunglitter, present in the middle portion of the image, appears as a gray-like color.

5. Conclusion

The data *in-situ* data obtained at the VIERS site will be used to help develop a better understanding of the impact of dust aerosols on the ocean color analysis performed on the SeaWiFS images shown above. In particular, the data I gathered at the VIERS site will aid in constructing more accurate models of dust properties for use in the analysis of satellite data. Also, the information I gathered on the background sea-salt aerosol properties will add to my previously obtained sea-salt data and aid in the understanding of future measurements of aerosol optical properties over the ocean. Finally, this trip has shown that the VIERS site is well suited to the study of Saharan dust aerosols over the open ocean. The data and experience I acquired during this measurement program will aid any possible future aerosol related work in the Virgin Islands area.

Acknowledgments

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